

INDIAN RIVER LAGOON-NORTH FEASIBILITY STUDY

Evaluation of Causeway Impacts on Aquatic Biota within the Indian River Lagoon-North Study Area

Summary: Various evaluations were performed in order to determine whether the partial or complete removal of existing causeways within the Indian River Lagoon-North study area would significantly improve any aspect of water quality or the biota in the lagoon. Results from the 2003 modeling study to determine causeway effects on seagrass indicated that full or partial removal of these structures would not significantly benefit seagrass distribution. Comparisons were also made between 1943 seagrass coverage, prior to most causeway construction, and 2003 seagrass coverage and concluded that there are no obvious near-field effects attributable to causeways. A statistical analysis of seagrass coverage before and after causeway construction was performed and indicated no significant differences. Evaluation of juvenile fishes and crustacean data collected between 1998-2002 within northern Indian River Lagoon showed a clear decline in diversity and abundance relative to the distance from inlets. While not collected in a manner designed specifically for causeway impact evaluation, it was recognized that this decline is more likely due to the life history of many of these species and distance from inlet rather than as a result of poor water quality or other impediment to transport. Recent larval fish research indicates that the causeways do not seem to act as complete barriers to many offshore-spawned larval fishes as densities for these species were relatively high even in areas farthest from the inlets. A tracking study of hard clam larvae indicated that the 520 causeway did constrain water flow and some larvae in the Banana River portion of the lagoon. However, tracking indicated that larvae were found to eventually disperse throughout the study area. Monitoring of resident fishes shows that spawning success is probably limited due to habitat (e.g. seagrasses) rather than by causeway impacts. A macroinvertebrate study was considered but eventually abandoned due to the difficulty in separating potential causeway effects from other factors. In conclusion, there appears to be no solid and compelling scientific evidence that partial or full removal of existing causeways in micro-tidal portions of the study area could have a significant positive effect on seagrass coverage and aquatic fauna within the lagoon. Therefore, no further effort on this issue is recommended unless appropriate evidence to the contrary is provided. It is recognized that the actual placement of fill to construct the causeways, which was done pre-U.S. Clean Water Act and the Section 404 permitting program, most likely destroyed seagrass and other benthic communities within and very near the causeway footprint. Additional loss of seagrass by future causeway construction or any other projects requiring filling is highly discouraged due to the difficulty in performing successful mitigation in compliance with federal and state permitting programs. It is also recognized that the study area has been degraded by factors other than causeways, which shall continue to be addressed by the Indian River Lagoon-North Feasibility Study (IRLN) project.

1. Introduction

The Ecological Sub-team, in support of the IRLN, evaluated whether partial or full removal of causeways within the study area would cause a positive impact on lagoon biota. This evaluation was based on the premise that these raised roadways may act as a physical barrier or degrade water quality as a result of impeding water flow and flushing. In general, they can be described as being built on fill with various

sized bridge span openings and located in micro-tidal areas of the lagoon. Recent modeling results indicated that full or partial removal of these structures would not significantly benefit seagrass, the study's primary biological indicator. Personnel from various agencies questioned whether the model was sufficiently accurate to predict localized impacts on seagrass. Additional questions were raised concerning causeway effects on larval fish distribution and macroinvertebrates, which the model was not designed to address. The following sections attempt to present a discussion of the evaluations performed on whether causeways do adversely affect seagrass and fisheries. A section is also included on a proposed study to assess causeway impacts on macroinvertebrates. The proposed macroinvertebrate study was abandoned due to time and funding constraints, but more importantly, its results could be affected by many factors other than causeways.

2. Seagrass

The following excerpt is from the Executive Summary of the "Preliminary Study of the Effects of Causeway Removals in the Indian River Lagoon" by Morris et al., 2003: "The impacts of causeways on seagrass in the Indian and Banana River Lagoons have been debated for many years (see Attachment 1, Causeway Location Map). The recent development of a hydrodynamic and water quality model for the lagoon allowed for simulation of causeway removals, and predicted the impacts of their removals on seagrasses. The model domain included the area between Ponce de Leon Inlet and the St. Lucie Inlet, while the model results were evaluated for the causeways between Haulover Canal and Wabasso. Different scenarios were evaluated, including full and partial causeway removals and watershed flow reductions were simulated to test the sensitivity of the model. Model results in the form of changes in surface velocity, flushing, flow volume, salinity, total suspended solids and incident light, were analyzed. The model accuracy, as determined by the model developer, was used to compare results. It is concluded that neither full nor partial removal of causeways will significantly benefit seagrass distribution in the Indian or Banana River Lagoons. In fact, [short term] negative impacts may be caused as a result of causeway removals. Previous modeling studies in the Indian River Lagoon (Evink, 1980) and Laguna Madre, TX (Powell et al., 1997) found similar results." The complete report can be found at the following website:

http://www.evergladesplan.org/pm/studies/study_docs/irl_north/100903_irl_north_causeway_report.pdf

In order to further analyze the effect of causeways on seagrass, St. Johns River Water Management District (SJRWMD) biologists compared IRLN seagrass coverage in 1943, prior to most causeway construction, to the most recent seagrass coverage in 2003. To compare seagrass acreage before and after, in GIS, 100-m-wide strips parallel to each causeway were established. The zero line was the center of the causeway. Seagrass acreage within each of these strips was calculated in 100-m increments up to 1,000 m away from the causeway (see Attachment 2). For a broad look, data were lumped and plotted as total seagrass

within each 100-m-wide band north, south, east, and west of the causeway. The footprint of the causeway was subtracted so that even the first 100-m strip compares only bottom areas with overlying water, both in 1943 and 2003. There were 7 causeways constructed after 1943: Titusville RR, NASA (2 lagoons), 528 (2 lagoons), Pineda, and Wabasso. In addition, as a control, the other 5 causeways constructed before 1943 were included. There was no consistent pattern. In 4 cases, 2003 was consistently greater than 1943. In 4 other cases, 1943 was consistently higher than 2003. In 3 cases, there was a consistent trend of increasing seagrass with increasing distance from the causeway. It may take further finer analyses, e.g., south versus north on the same side of the lagoon, to detect possible patterns associated with sub-segments and any possible abrupt changes in water quality. The broad conclusion based on limited data, however, is that there are no obvious near-term effects of causeways on seagrass (R. Virnstein, SJRWMD, 2004, personal communication).

A statistical analysis was also performed in order to test whether there are significant differences in seagrass coverage before and after causeways were constructed. In summary, from a time perspective, no significant differences from 1943 to 1986, either with or without causeways was observed. From a spatial perspective, only one north-south significant difference within the same year was found. Finally, no significant differences between years for each study quadrant were observed, with or without causeways (R. Virnstein, SJRWMD, 2004, personal communication).

3. Fisheries

Florida Fish and Wildlife Conservation Commission (FWC) biologists presented data to the Ecological Sub-team on juvenile fishes and crustaceans collected by using 21.3-m seines during stratified random sampling in the Indian River and Banana River Lagoons, May to November 1998-2002. The objective of the sampling was to characterize the status of fish populations lagoon wide and was not intended to evaluate whether causeways adversely impact juvenile fish and crustacean abundance or diversity. FWC also believes that a mobile fish fauna may be inappropriate for evaluating potential causeway impacts on the IRLN study area. Modeling of how causeways influence fish or macroinvertebrate larval distribution or macroinvertebrate surveys specifically designed to address this issue may be more appropriate. Nonetheless, the existing data set is comprehensive and least-square mean abundances for selected species were plotted by region in an attempt to discern whether there was an obvious decline near the causeways (see Attachment 3). Additionally, species rarefaction curve was used to evaluate if there were changes in diversity of the fish community in respect to the location of the causeways. The data not being designed specifically for causeway impact evaluation can lead to relatively large error in the analysis and any general overall patterns should be cautiously evaluated. As expected, there exists a clear decline in diversity and abundance relative to the distance from the inlet in the data presented. The decline is likely a result of the life history of many of the fishes and distance to

inlet rather than a result of poor water quality or other impediment to transport. Many fishes are spawned in nearshore or offshore waters and utilize the estuary as juvenile habitat. These fishes enter the estuary through the inlet and settle into the nearest available nursery habitats. Therefore, the fish diversity and abundance declines in response to the settlement of these fishes as they move farther away from the inlet areas. If there were a negative impact on the fisheries from the causeways, one would expect to see precipitous declines in abundance or diversity in the proximity of each causeway, which was not apparent in the data presented. Although no declines were found around the causeways it does not mean that there is no impact from the causeways. It is just not evident in the data that has been presented. Even if impacts were apparent it would be difficult to separate the impacts of the causeway from impacts caused by increased urbanization i.e., increased runoff, loss of shoreline or seagrass habitat (R. Paperno and C. Harnden, FWC, 2004, personal communication).

Florida Institute of Technology (FIT) researchers evaluated spatial distribution of larval fishes in the North Indian River Lagoon Complex during an ongoing two-year study beginning August 2002. Like the FWC evaluation, several important caveats need to be taken into consideration when looking at this data. Specifically, the study was not designed to look at causeway effects, the results represent less than two years of data, and post-settlement mortality (juvenile mortality) was not examined. However, the researchers feel that the preliminary data are strong enough to indicate that the causeways do not seem to act as complete barriers to many offshore-spawned larval fishes as densities for these species were relatively high even in areas farthest from the inlets. Although only limited collections were made near the inlets, the FIT biologists feel that the density of offshore-spawned larval fishes is undoubtedly much higher at ingress points. The overall relatively low densities of these taxa observed in the region are more likely the result of the distance from the inlets. They also concluded that there might be an important effect on the much smaller (i.e., largely passively distributed), locally spawned larvae (e.g. spotted seatrout), not primarily due to the causeways acting as physical barriers to dispersal although this they feel may be important as well, but by compartmentalizing differences in water quality parameters that influence larval survival. The FIT researchers have stated that in order to get at the causeway effect on resident larvae, one would need to take an IRLN circulation model like the one that the SJRWMD has, and incorporate it with a particle-transport model in which certain larval fish behaviors (pelagic duration, vertical migration, etc.) could be accounted for. This has been done elsewhere but not in the Indian River Lagoon (E. Reyier, FIT, 2004, personal communication).

Arnold et al., 2004 (in draft), tracked larvae movements of the hard clam *Mercenaria* in the Banana River portion of the Indian River Lagoon. To some extent, this study simulated the particle-transport model that FIT recommended. Results of the tracking indicated that the 520 causeway constrained flow (and some associated larvae) from north to south along the central portion of the lagoon and caused larvae to distribute toward the eastern and western margins of the lagoon. However,

tracking indicated that larvae were found to eventually disperse throughout the study area. Utilizing the Pollutant Load Reduction model previously designed for the Indian River Lagoon, the SJRWMD found that a crude approximation of hard clam larvae migration distances and rates could be derived from the surface velocity evaluation assuming the larva is planktonic and neutrally buoyant in the surface layer of the water column. Only velocities in the northerly and southerly directions were considered since these directions would be most influenced by the causeways. Due to many factors, it would be highly unlikely for a larva to drift in only one direction for a whole day, but if it did, it would travel 1 km/day farther with the removal of the causeways (J. Steward, SJRWMD, 2004, personal communication).

An effort was made by SJRWMD biologists to evaluate causeway effects on spawning activity of resident species, specifically spotted seatrout. Transects were run at night during July 2004 from south of Eau Gallie Causeway to Brewer Causeway. Identification of species and spawning sites was performed using acoustics. Spotted sea trout spawning activity was not detected in the southern stretch of this area. Spawning activity was first observed at Pineda Causeway and then again at channel marker 83, about 0.5 miles south of the 520 Causeway, and then detected consistently and at high densities. Their conclusion was that causeways do not appear to be impacting spotted sea trout spawning activity since spawning was observed on both sides of causeways (R. Brockmeyer, SJRWMD, 2004, personal communication).

In their stock assessment report for spotted seatrout in the northeast region of the state, the Fish and Wildlife Research Institute stated that recruitment of age-0 spotted seatrout appears to be variable but stable (Murphy 2003). The majority of the data input into the east coast assessment is from the IRLN (R. Paperno, FWC, 2004, personal communication).

4. Macroinvertebrates Proposed Study

The Department of Environmental Protection Southeast District (DEP SED) Ambient Water Quality section investigated the viability of designing a study that would provide statistically supportable evidence concerning the impact of IRLN causeways on biological health. Their draft proposal suggested using macroinvertebrate sampling to monitor biological communities in the vicinity of several causeways near Cocoa, Florida. Abiotic factors such as bottom sediment characteristics, water quality, vegetative cover, and land use would also be monitored in an attempt to associate differences in biological community structure with differences in environment. Differences in environmental conditions would then be associated to the presence of causeways. A reconnaissance survey using ponar benthic sediment grabs was performed in the IRLN in May 2004 near Pineda Causeway south of Cocoa. The survey indicated this study might be difficult to successfully execute. Short-term measurement of a few environmental metrics (% organics, sediment pollutants, water column dissolved oxygen) in the vicinity of causeways may not be sufficient to support a hypothesis that causeways degrade

environmental conditions. The recon survey also suggested that the existence of patchy macroalgae cover in the area would be most acceptable for benthic biotic sampling. This would add another confounding factor to the study design and suggested that a larger number of samples would be required to discern existence of any association between community metrics and proximity to causeways. The limitation of study expenditures would likely result in an insufficient sampling effort needed to achieve robust statistical analysis. With the observed patchiness in bottom substrate characteristics and macroalgae coverage and the myriad of other confounding factors (flow patterns, season, local pollutant sources, wave height (fetch), etc.) sampling at the proposed rate near only two causeways may be too limited to support any conclusions concerning benthic community differences related to distance from causeway. Additionally the observed patchiness in sediment characteristics (relative to distance from causeway) indicated it is unlikely that a discernable association between distance from causeway and change in sediment characteristics exists. If this effort was successful in finding an association between degraded environmental metrics near a causeway and changes in benthic biotic metrics, the usefulness of this information may be limited depending on what the true concern is. At its best, this study design would associate localized change in benthic community structure to the close proximity of causeways. Expansion of this finding to a broader area of concern would be questionable. These considerations support a decision to discontinue the proposed study as it is now designed (M. Thompson, FDEP, 2004, personal communication).

5. Conclusion

In accordance with U.S. Army Corps of Engineers (Corps) Regulations concerning Civil Works Projects (part 3-5 of ER 1105-2-100), the Jacksonville District believes that the value of ecosystem restoration outputs or “environmental lift” that would be realized from modifications to the causeways would not equal or exceed their cost. Continued analysis of this component of the IRLN study cannot be justified. This finding is based on the conclusion reached by the project sponsors, the Corps and SJRWMD, that there appears to be no solid and compelling scientific evidence that existing causeways in micro-tidal areas have a significant negative impact on adjacent aquatic biota. Therefore, no further effort on this issue is recommended unless appropriate evidence to the contrary is provided by a third party which supports that causeways have a significant negative impact on resources within IRLN. It is recognized that the actual placement of fill to construct the causeways, which was done pre-U.S. Clean Water Act and the Section 404 permitting program, most likely destroyed seagrass and other benthic communities within and very near the causeway footprint. Additional loss of seagrass by future causeway construction or any other projects requiring filling is highly discouraged due to the difficulty in performing successful mitigation in compliance with federal and state permitting programs. It is also recognized that the study area has been degraded by factors other than causeways, which shall continue to be addressed by this project.

6. List of Preparers

NAME	AGENCY-TITLE	CONTRIBUTION
Ron Brockmeyer	St. Johns River Water Management District-Biologist	Fisheries
Chris Harnden	Florida Fish and Wildlife Conservation Commission-Biologist	Fisheries
Richard Paperno	Florida Fish and Wildlife Conservation Commission-Biologist	Fisheries
Eric Reyier	Florida Institute of Technology-Phd Candidate	Fisheries
Joel Steward	St. Johns River Water Management District-Biologist	Fisheries
Paul Stodola	U.S. Army Corps of Engineers-Biologist	Coordination and Editing
Mark Thompson	Florida Department of Environmental Protection-Biologist	Macroinvertebrates
Robert Virnstein	St. Johns River Water Management District-Biologist	Seagrass

7. References

Arnold, W.S., G.L. Hitchcock, M.E. Frischer, R. Wannikhof, and Y.P. Sheng. 2004 (in draft). *Dispersal of an Introduced Larval Cohort in a Coastal Lagoon*. 26 pp.

Evink, G.L. 1980. *Studies of the Causeways in the Indian River, Florida*. A report to the Florida Department of Transportation (FL-ER-7-80). Tallahassee, FL, 141 pp.

Morris IV, F.W., D. Christian, J. Steward, and M.G. Cullum. 2003. *Preliminary Study of the Effects of Causeway Removals in the IRL*. A report in support of the Indian River Lagoon North Feasibility Study, Palatka, FL, 18 pp.

Murphy, M.D. 2003. *A Stock Assessment of Spotted Seatrout **Cynoscion nebulosus** In Florida: Status of the Stocks through 2001*. Florida Fish and Wildlife Conservation Commission-Florida Marine Research Institute, St. Petersburg, FL, 98 pp.

Powell, G.L., J. Matsumoto, W.L. Longley, and D.A. Brock. 1997. *Effects of Structures and Practices on the Circulation and Salinity Pattern of the Corpus Christi Bay National Estuary Program Study Area*. Corpus Christi Bay National Estuary Program. Corpus Christi, TX, 169 pp.

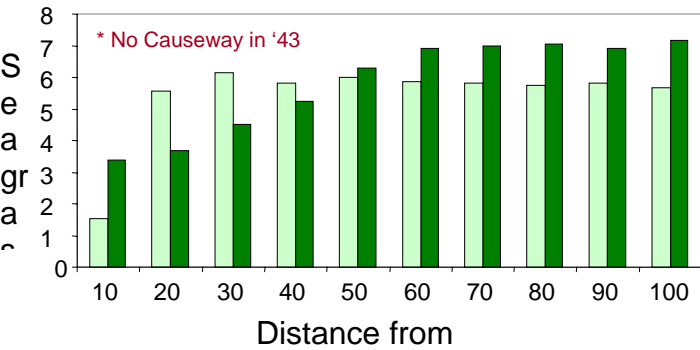
ATTACHMENT 1



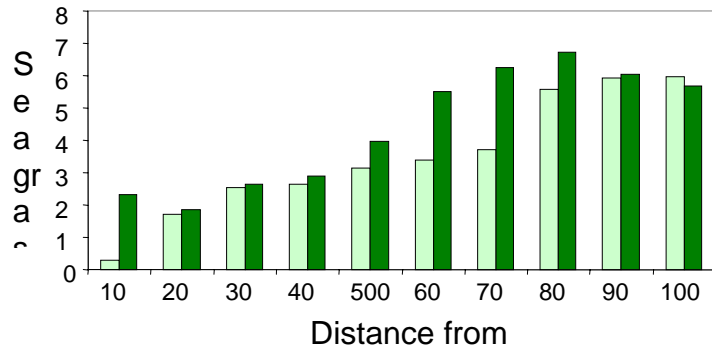
ATTACHMENT 2

Do Causeways Affect Seagrass?

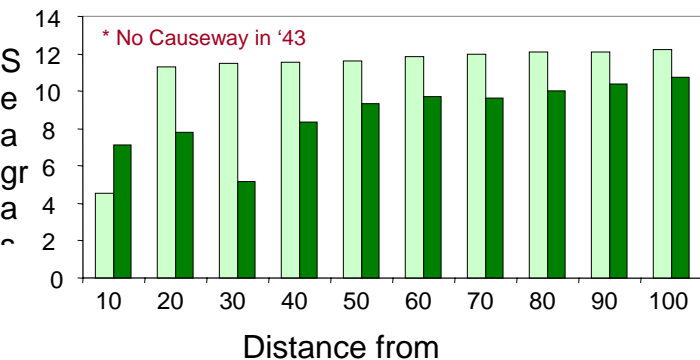
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Indian River Lagoon**



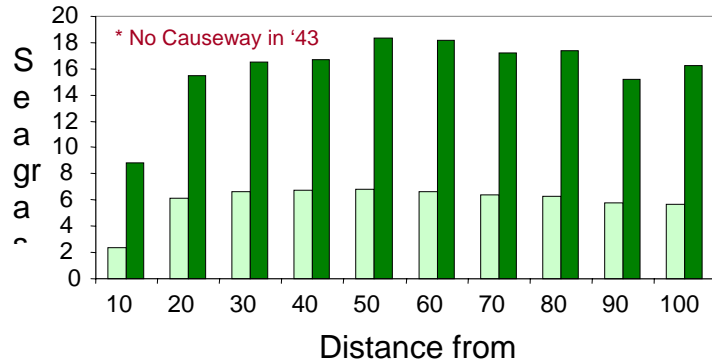
**Brewer Causeway
(SR406)**



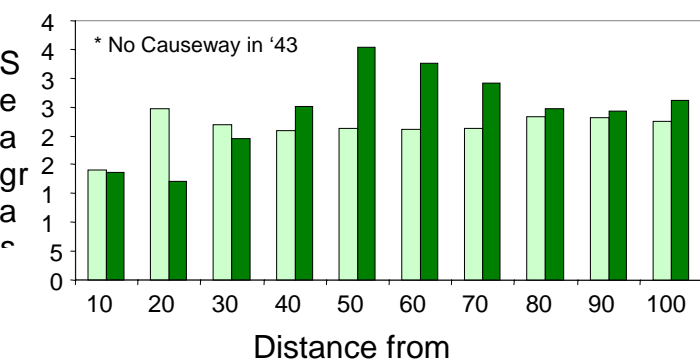
**NASA Causeway*
Indian River Lagoon**



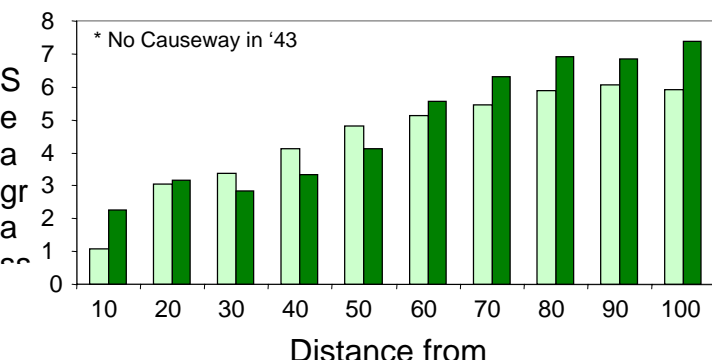
**NASA Causeway*
Banana River**



**528 Causeway*
Indian River Lagoon**



**528
Causeway***



(Source: SJRWMD 2004)

* No Causeway in '43



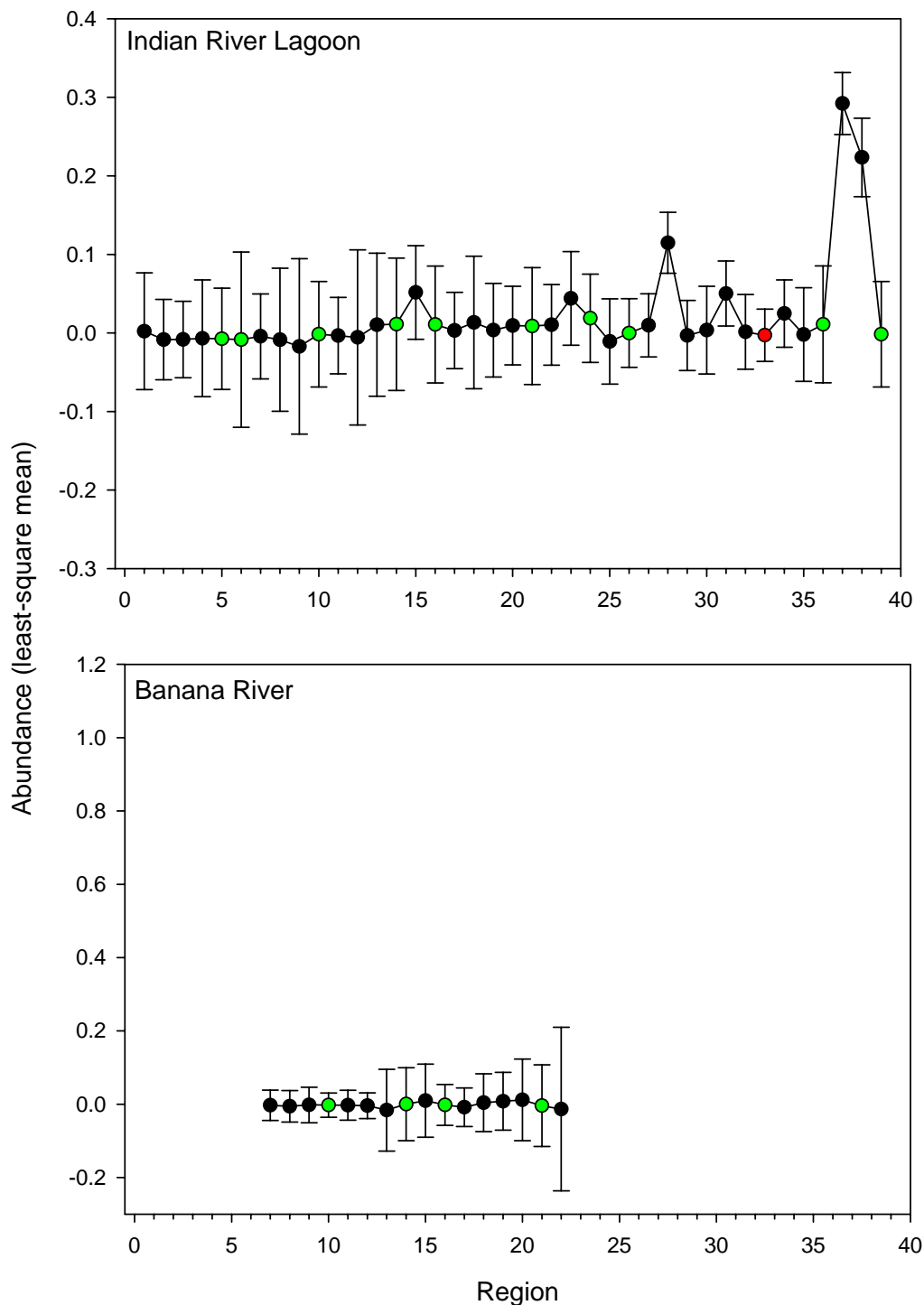
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2003

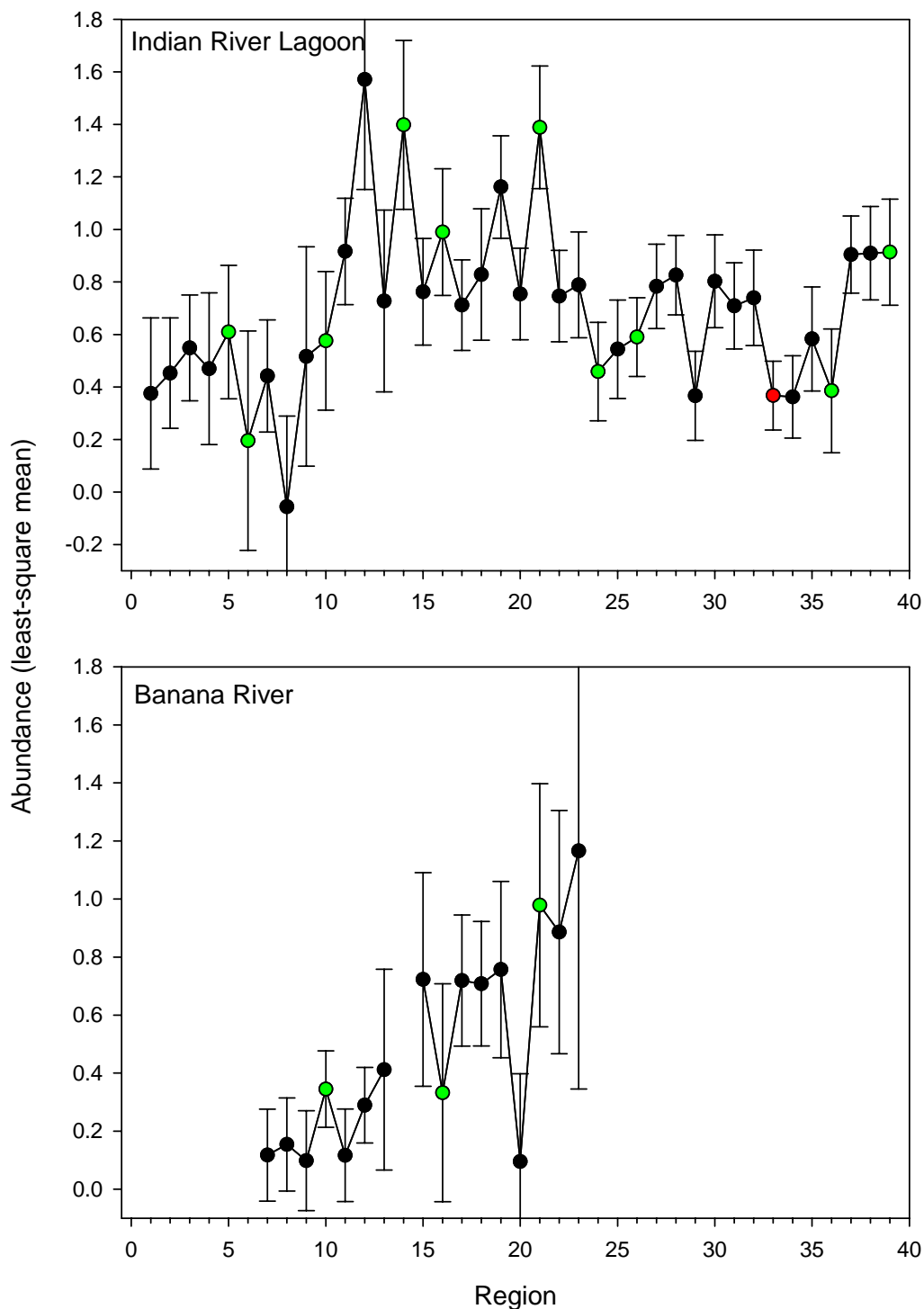
ATTACHMENT 3

Centropomus undecimalis



Least-square mean abundances of juvenile snook, *Centropomus undecimalis*, (≤ 40 mm SL) collected in 21.3-m seines during stratified-random sampling in the Indian River Lagoon, September to January 1998-2002. Region represents grid clusters along a latitudinal gradient (northernmost Region 1 to southernmost Region 39) in the Indian River Lagoon and Banana River. Causeway grid clusters (●) are represented as follows: Region 5 (Railroad Bridge), Region 6 (Titusville Causeway), Region 10 (NASA Causeway), Region 14 (SR 528), Region 16 (SR 520), Region 21 (Pineda Causeway), Region 24 (Eau Gallie Causeway), Region 26 (Melbourne Causeway), Region 36 (Wabasso Causeway), Region 39 (Barber Bridge). Region 33 represents Sebastian Inlet grids (●).

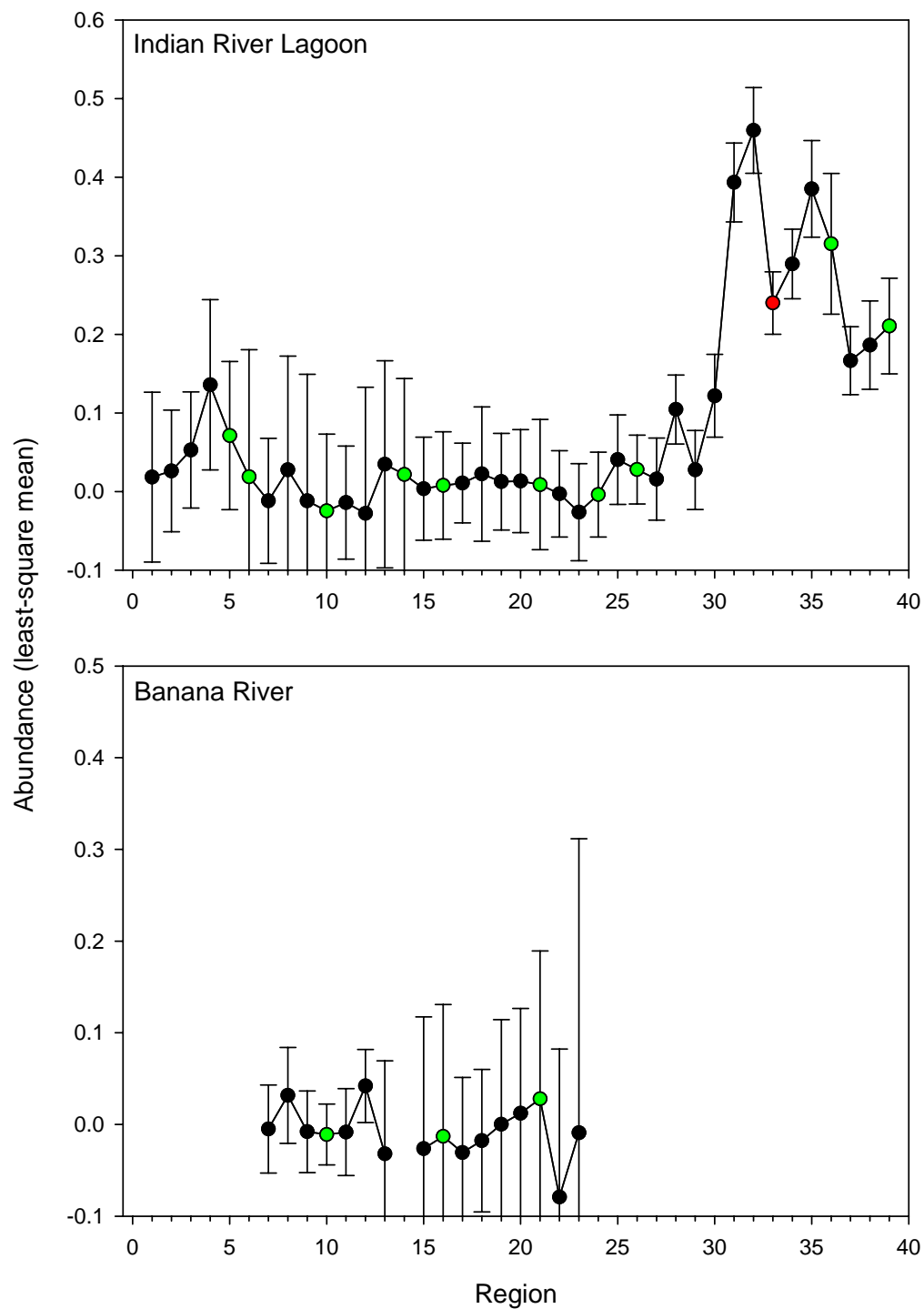
Cynoscion nebulosus



Least-square mean abundances of juvenile spotted seatrout, *Cynoscion nebulosus*, (≤ 100 mm SL) collected in 21.3-m seines during stratified-random sampling in the Indian River Lagoon, May to November 1998-2002. Region represents grid clusters along a latitudinal gradient (northernmost Region 1 to southernmost Region 39) in the Indian River Lagoon and Banana River. Causeway grid clusters (●) are represented as follows: Region 5 (Railroad Bridge), Region 6 (Titusville Causeway), Region 10 (NASA Causeway), Region 14 (SR 528), Region 16 (SR 520), Region 21 (Pineda Causeway), Region 24 (Eau Gallie Causeway), Region 26 (Melbourne Causeway), Region 36 (Wabasso Causeway), Region 39 (Barber Bridge). Region 33 represents Sebastian Inlet grids (●).

SOURCE: FWC 2004

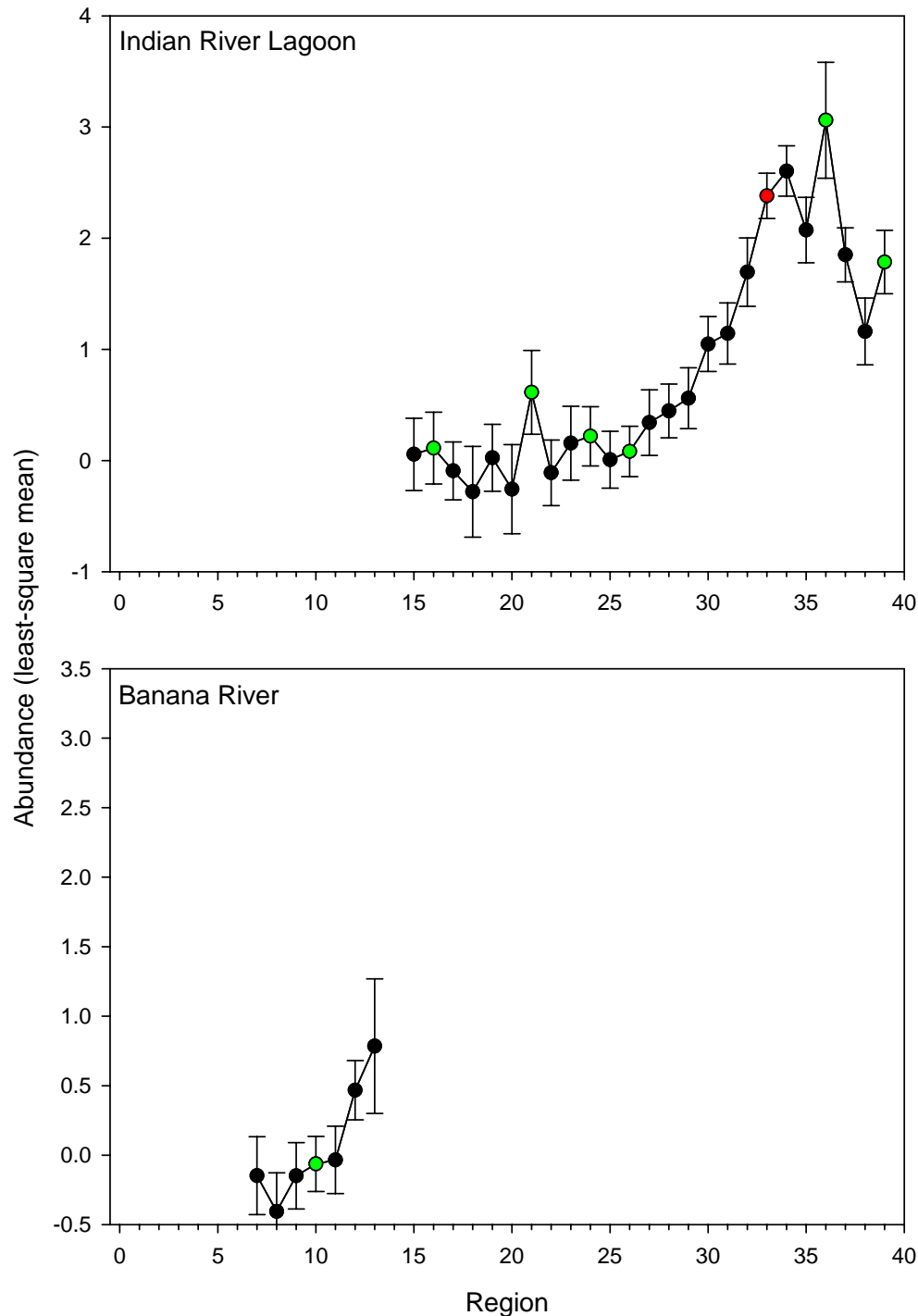
Callinectes sapidus



Least-square mean abundances of juvenile blue crabs, *Callinectes sapidus*, (≤ 65 mm CW) collected in 21.3-m seines during stratified-random sampling in the Indian River Lagoon, September to June 1998-2002. Region represents grid clusters along a latitudinal gradient (northernmost Region 1 to southernmost Region 39) in the Indian River Lagoon and Banana River. Causeway grid clusters (●) are represented as follows: Region 5 (Railroad Bridge), Region 6 (Titusville Causeway), Region 10 (NASA Causeway), Region 14 (SR 528), Region 16 (SR 520), Region 21 (Pineda Causeway), Region 24 (Eau Gallie Causeway), Region 26 (Melbourne Causeway), Region 36 (Wabasso Causeway), Region 39 (Barber Bridge). Region 33 represents Sebastian Inlet grids (●).

SOURCE: FWC 2004

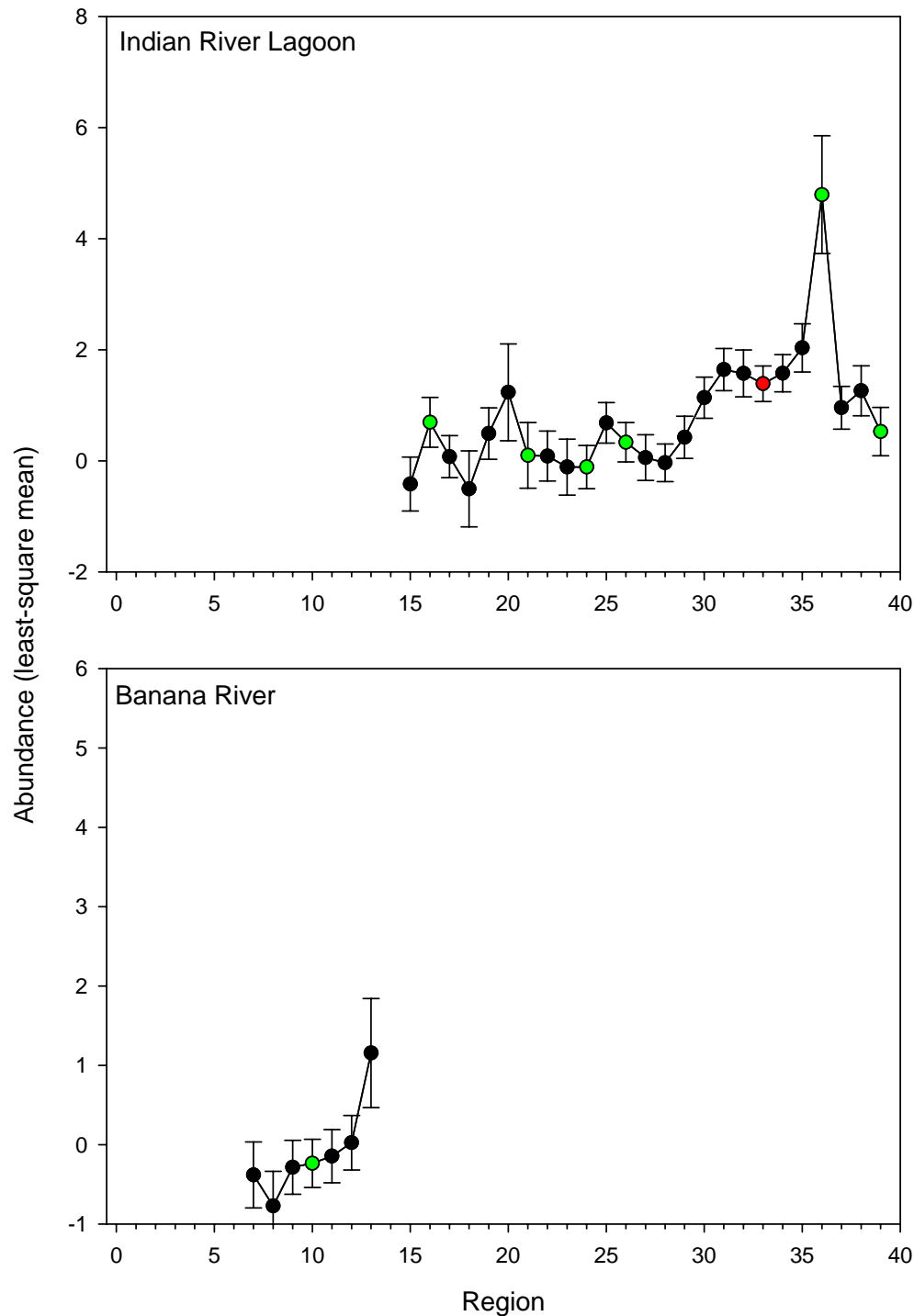
Lagodon rhomboides



Least-square mean abundances of juvenile pinfish, *Lagodon rhomboides*, (≤ 80 mm SL) collected in 21.3-m seines during stratified-random sampling in the Indian River Lagoon, January to June 1998-2002. Region represents grid clusters along a latitudinal gradient (northernmost Region 1 to southernmost Region 39) in the Indian River Lagoon and Banana River. Causeway grid clusters (●) are represented as follows: Region 5 (Railroad Bridge), Region 6 (Titusville Causeway), Region 10 (NASA Causeway), Region 14 (SR 528), Region 16 (SR 520), Region 21 (Pineda Causeway), Region 24 (Eau Gallie Causeway), Region 26 (Melbourne Causeway), Region 36 (Wabasso Causeway), Region 39 (Barber Bridge). Region 33 represents Sebastian Inlet grids (●).

SOURCE: FWC 2004

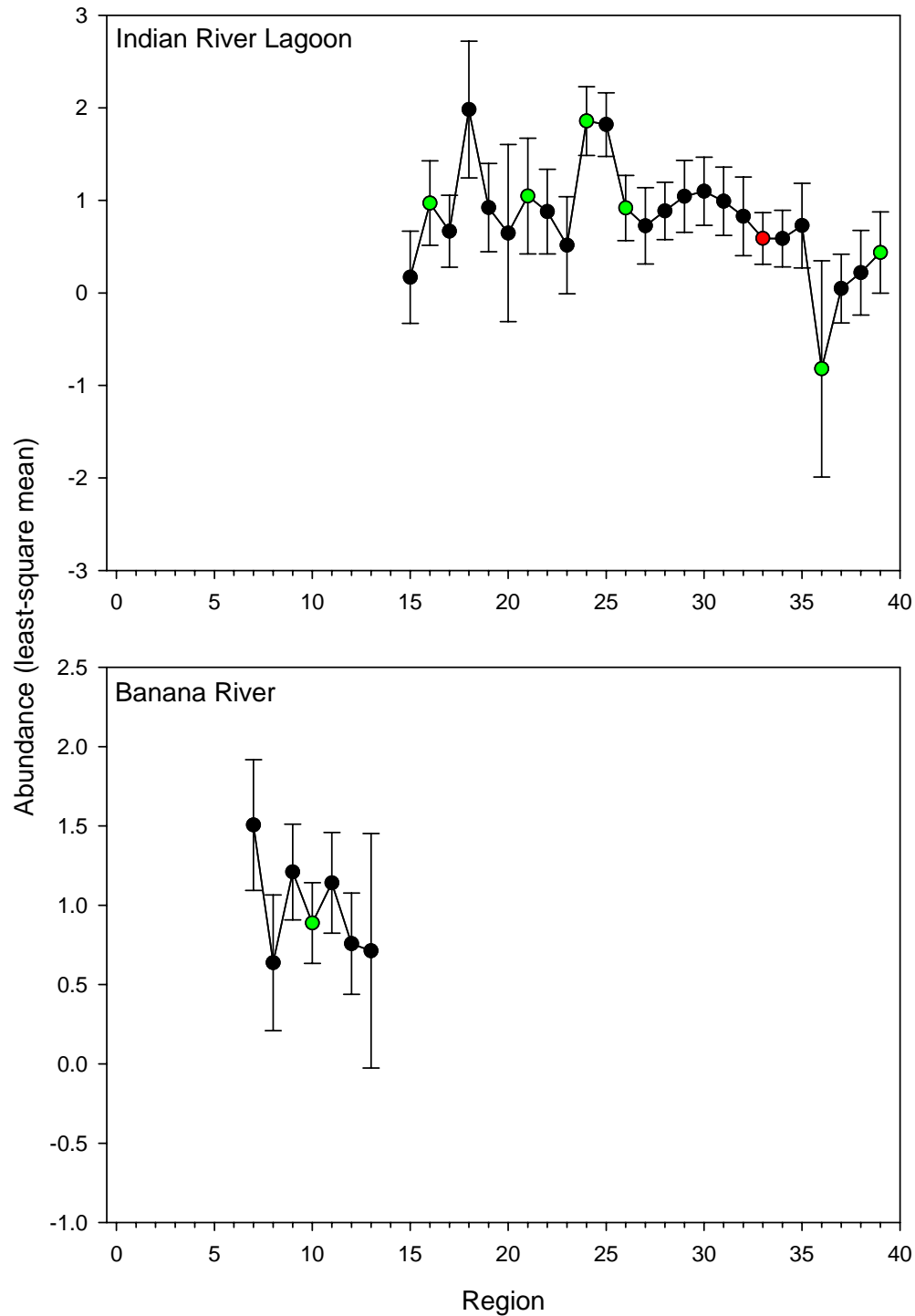
Leiostomus xanthurus



Least-square mean abundances of juvenile spot, *Leiostomus xanthurus*, (≤ 40 mm SL) collected in 21.3-m seines during stratified-random sampling in the Indian River Lagoon, January to April 1998-2002. Region represents grid clusters along a latitudinal gradient (northernmost Region 1 to southernmost Region 39) in the Indian River Lagoon and Banana River. Causeway grid clusters (●) are represented as follows: Region 5 (Railroad Bridge), Region 6 (Titusville Causeway), Region 10 (NASA Causeway), Region 14 (SR 528), Region 16 (SR 520), Region 21 (Pineda Causeway), Region 24 (Eau Gallie Causeway), Region 26 (Melbourne Causeway), Region 36 (Wabasso Causeway), Region 39 (Barber Bridge). Region 33 represents Sebastian Inlet grids (●).

SOURCE: FWC 2004

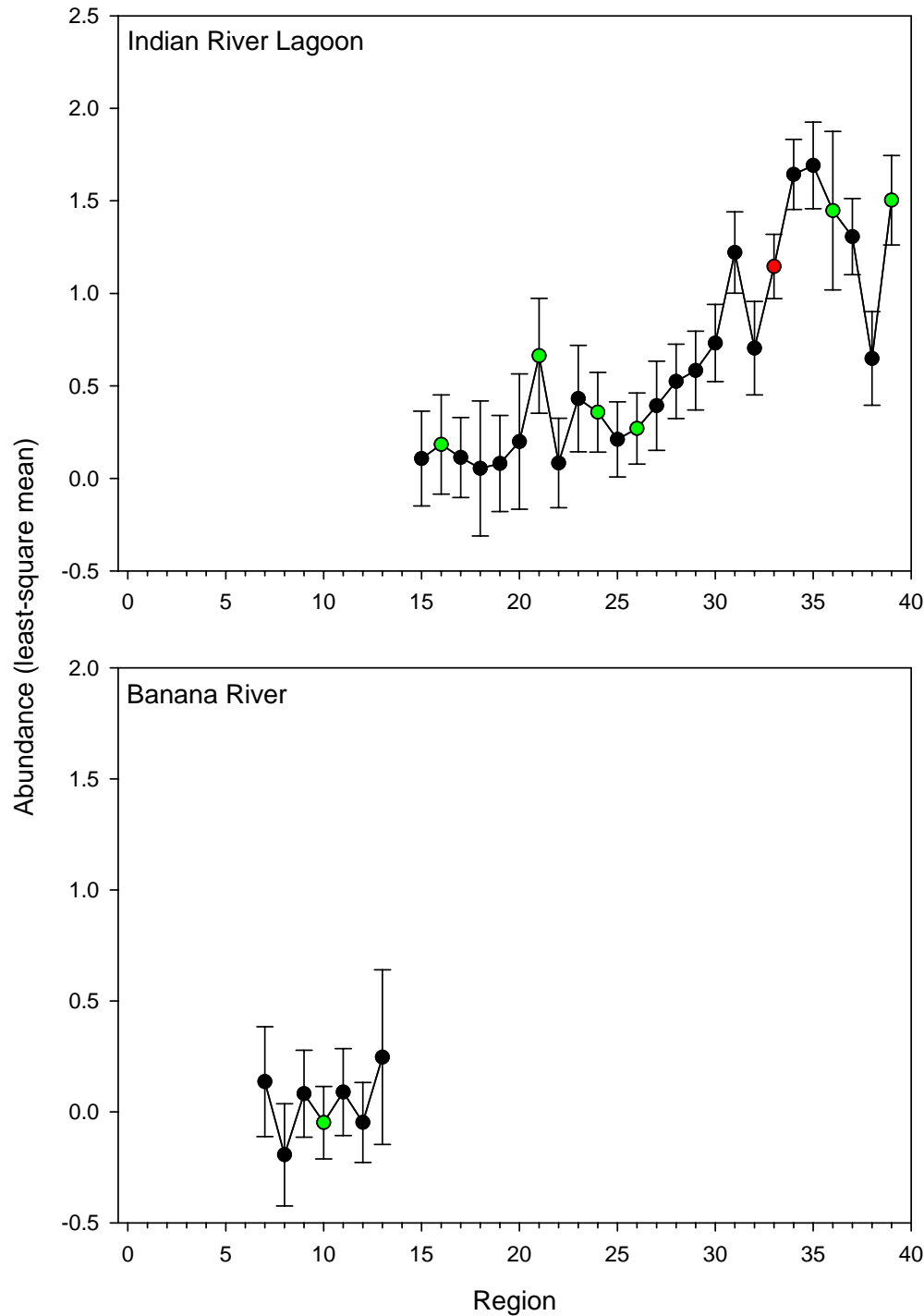
Mugil cephalus



Least-square mean abundances of juvenile striped mullet, *Mugil cephalus*, (≤ 35 mm SL) collected in 21.3-m seines during stratified-random sampling in the Indian River Lagoon, January to April 1998-2002. Region represents grid clusters along a latitudinal gradient (northernmost Region 1 to southernmost Region 39) in the Indian River Lagoon and Banana River. Causeway grid clusters (●) are represented as follows: Region 5 (Railroad Bridge), Region 6 (Titusville Causeway), Region 10 (NASA Causeway), Region 14 (SR 528), Region 16 (SR 520), Region 21 (Pineda Causeway), Region 24 (Eau Gallie Causeway), Region 26 (Melbourne Causeway), Region 36 (Wabasso Causeway), Region 39 (Barber Bridge). Region 33 represents Sebastian Inlet grids (●).

SOURCE: FWC 2004

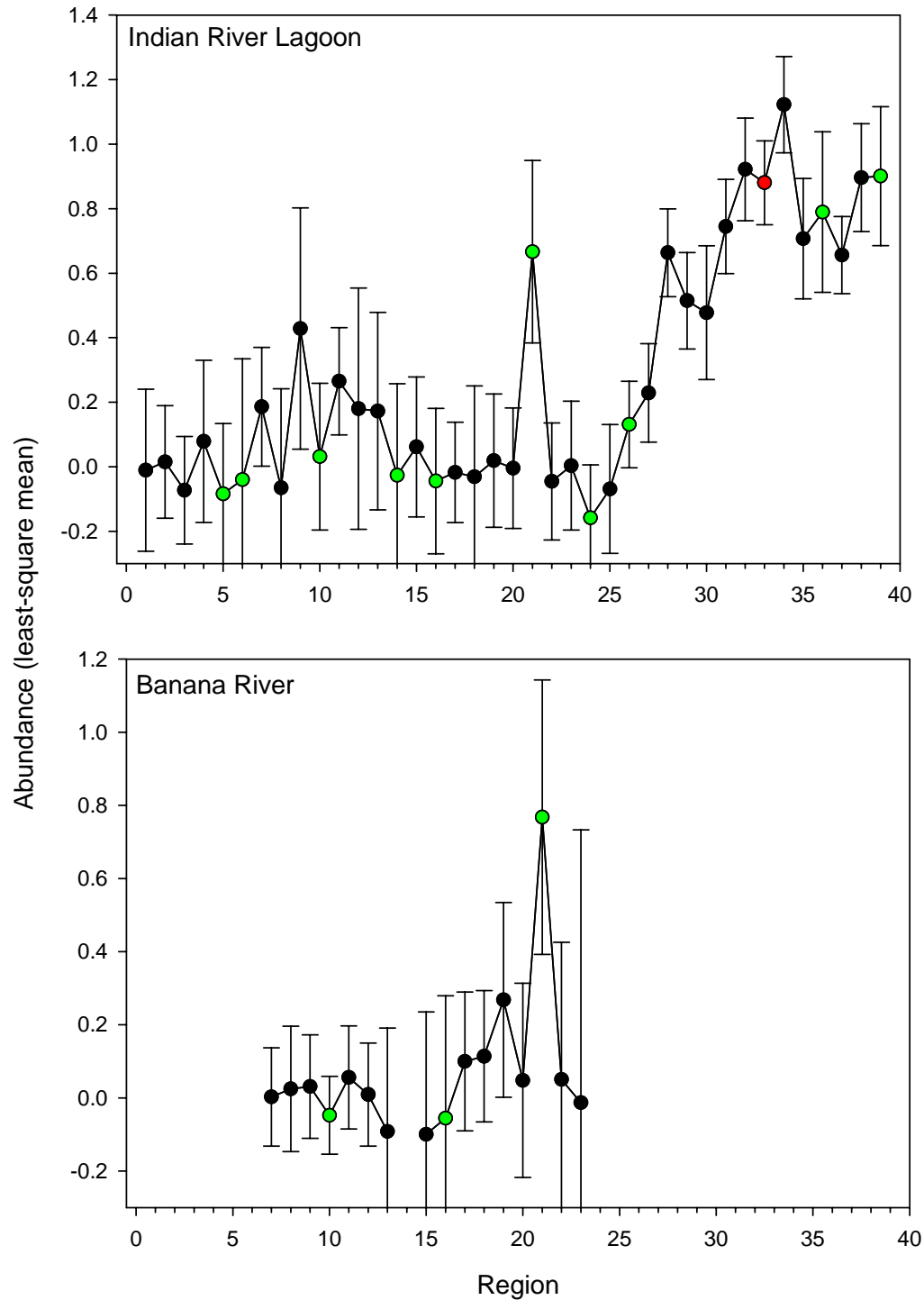
Orthopristis chrysoptera



Least-square mean abundances of juvenile pigfish, *Orthopristis chrysoptera*, (≤ 40 mm SL) collected in 21.3-m seines during stratified-random sampling in the Indian River Lagoon, January to May 1998-2002. Region represents grid clusters along a latitudinal gradient (northernmost Region 1 to southernmost Region 39) in the Indian River Lagoon and Banana River. Causeway grid clusters (●) are represented as follows: Region 5 (Railroad Bridge), Region 6 (Titusville Causeway), Region 10 (NASA Causeway), Region 14 (SR 528), Region 16 (SR 520), Region 21 (Pineda Causeway), Region 24 (Eau Gallie Causeway), Region 26 (Melbourne Causeway), Region 36 (Wabasso Causeway), Region 39 (Barber Bridge). Region 33 represents Sebastian Inlet grids (●).

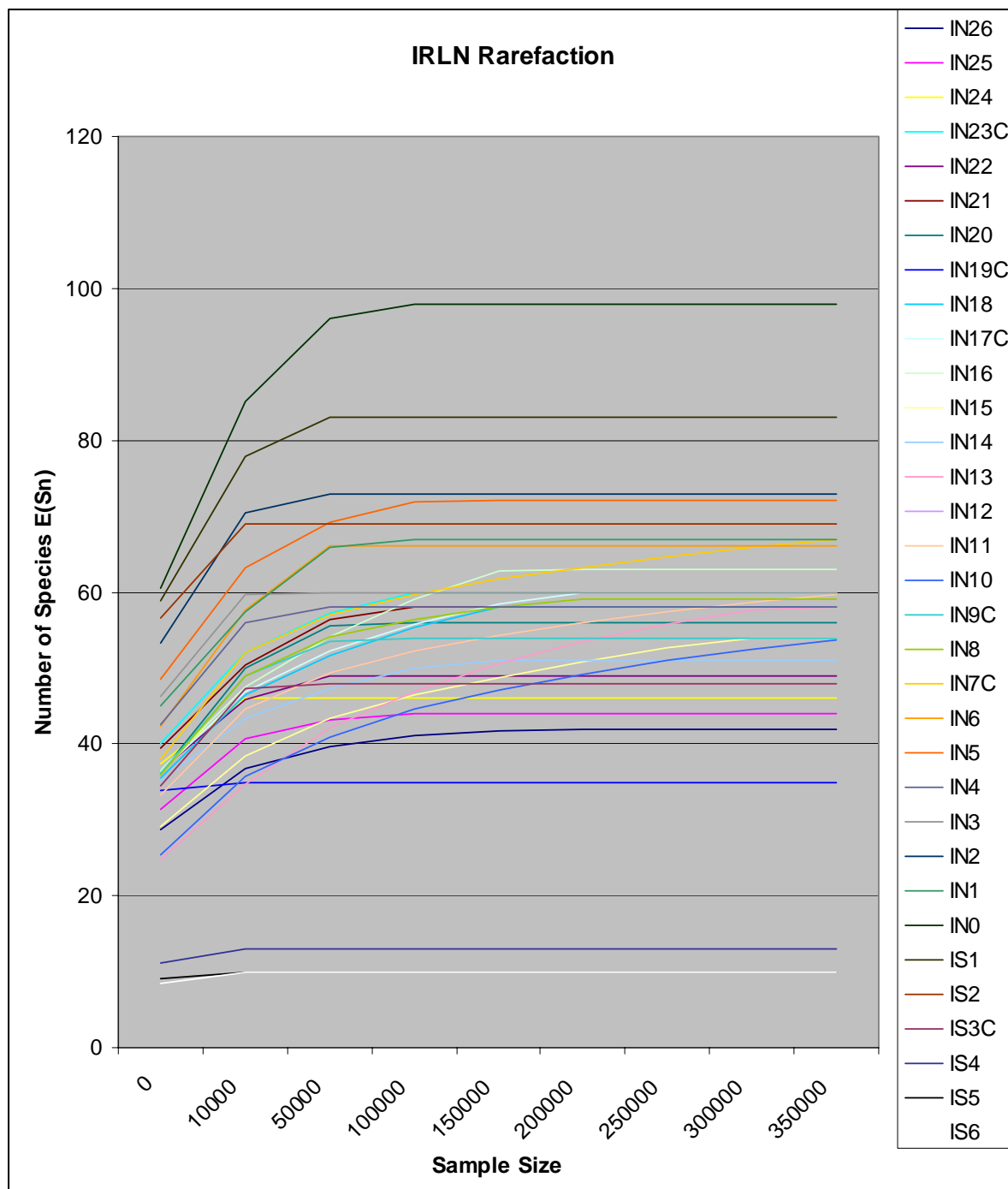
SOURCE: FWC 2004

Sciaenops ocellatus



Least-square mean abundances of juvenile red drum, *Sciaenops ocellatus*, (≤ 40 mm SL) collected in 21.3-m seines during stratified-random sampling in the Indian River Lagoon, September to January 1998-2002. Region represents grid clusters along a latitudinal gradient (northernmost Region 1 to southernmost Region 39) in the Indian River Lagoon and Banana River. Causeway grid clusters (●) are represented as follows: Region 5 (Railroad Bridge), Region 6 (Titusville Causeway), Region 10 (NASA Causeway), Region 14 (SR 528), Region 16 (SR 520), Region 21 (Pineda Causeway), Region 24 (Eau Gallie Causeway), Region 26 (Melbourne Causeway), Region 36 (Wabasso Causeway), Region 39 (Barber Bridge). Region 33 represents Sebastian Inlet grids (●).

SOURCE: FWC 2004



The legend indicates the rarefaction curve for each segment. "IN0" represents Sebastian Inlet. The "IN" indicates north of Sebastian Inlet. The "IS" indicates south of Sebastian Inlet. Those codes with a "C" indicate segments in which a causeway occurs.

SOURCE: FWC 2004

